

# ECE 4750/6750: Digital Signal Processing

## Spring 2017

### Logistics

Instructors: Jie Lian

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Office Hours: Wednesdays, from 10:00 AM – 11:45 AM, in Thornton Hall C-311

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Office Hours: Tuesdays, from 1:30 PM – 3:00 PM, in Rice Hall 309

TA's: Scott Patterson

Daniel Russell

Lecture: Date/time: Mondays, Wednesdays, 3:30 PM – 4:45 PM

Room: Thornton Hall E303

Textbook: A. V. Oppenheim and R. W. Schaffer. *Discrete-Time Signal Processing*, 3/E. Prentice-Hall, 2010. [required; may be purchased from UVA bookstore or online]

### Course Description

How do phones know which way is up, or to turn off the display when we hold them up to our ears? A hallmark of the digital revolution is how our devices interact, not only with their users, but with their surroundings. Digital Signal Processing (DSP) is an enabling technology of this revolution, allowing our smartphones, appliances, and even buildings to intelligently interact with their environment.

But, DSP is about so much more. How can we create spectacular images with tiny cameras? How does Siri (or Google or Cortana) know what I am asking? Can we program a computer to focus on a voice in a crowd or pick an instrument out of an orchestra? The common component in all these questions is signal processing – sampling, filtering, and analyzing measurements of the real world. This course will explore and apply these concepts in digital systems all around us.

### Course Structure

In this course, students learn DSP concepts via readings, in-class activities, and periodic homework. Having completed preparatory video lectures and readings before class, students will work together discussing the concepts and completing exercises using MATLAB software. This course is not intended to

teach MATLAB; students should already have background from prerequisite courses. These activities conclude with reflective writing exercises and feedback-oriented short quizzes. In addition to two midterm exams, students work in small teams over the semester to design a real DSP system of their own choosing (see project handout for details).

## Learning Goals and Objectives

This course is aimed at 3<sup>rd</sup>/4<sup>th</sup> year undergraduates and 1<sup>st</sup> year graduate students (who have not previously taken a DSP course) interested in understanding how (1) to analyze digital signals and design digital systems and (2) to apply DSP to complex real-world problems. By the end of this course, students should be able to:

1. Describe digital systems using frequency-domain and time-domain representations
2. Deduce and evaluate the behavior of digital systems using these representations
3. Analyze real signals using digital systems
4. Associate digital signal processing with other engineering disciplines and everyday life
5. Create a real digital system that fits the criteria of a given application or problem
6. Divide a complex real world problem into component problems and work as a team to manage the construction and integration of the solutions to those problems

## Evaluation

**Team Project (30%):** Students work in **teams of two/three** to complete a semester-long design project applying the concepts of digital signal processing covered in this class. Each team (1) selects a project (e.g., a voice recognition system or music synthesizer), (2) subdivides the project into simpler components, (3) implements solutions to each component (milestone), and (4) integrates those solutions into a real system. As a critical part of this project, students need to analyze and verify the functionality of the design, using real world signals or data. Grades are based on the team proposal, reporting on milestones, a final (group) presentation, and a final (individual) written report. This experience provides valuable experience working in groups, tackling real-world problems, and designing and analyzing a multi-component system. **The final presentations will take place during the scheduled final exam period.** If a team member is not present during the scheduled exam time for their final presentation, **that student will receive no credit for their entire project!** [Objectives 1-6]

**Class Exercises (30%):** In addition to the assigned video lectures and readings in preparation for class, students are expected to complete individual and group exercises related to the concepts taught in each class. Beyond reinforcing foundational knowledge, these activities involve creative or practical thinking through (1) peer instruction/problem solving (e.g., specifying and implementing filters) and (2) strategic problem solving (e.g., designing multi-stage systems). Individual activities include written reflections on topics like contrasting approaches to filter design in real systems. Submitted responses are due in advance of the next lecture. Other activities involve creating and modifying MATLAB code, **so bringing a laptop running MATLAB to class is highly recommended.** Most work is to be completed during lecture times, so attendance and participation is essential. [Objectives 1-5]

**Checkpoints** (5%): At the end of most weeks, students complete brief sets of 2-3 questions about the material covered in that week's video lectures and associated readings. These checks will provide quick feedback on understanding the covered concepts. The results of these quizzes are used to adapt and review concepts later in the course. [Objectives 1-3]

**Homework** (15%): Individual out-of-class assignments complement the readings and in-class activities, through both programming and written conceptual exercises. Homework is assigned roughly every three weeks, and each assesses foundational concepts and critical thinking skills. Students enrolled in ECE 6750 will complete additional problems on each homework assignment. [Objectives 1-5]

**Midterm** (20% total): Two graded exams given in class test the concepts covered in the course. While the exams are closed book/closed computer/closed notes, students are invited to prepare a single sheet of formulas or other material. Test problems are similar to the written components of homework or in-class problems. Students enrolled in ECE 6750 will complete additional take-home problems as part of each midterm exam. [Objectives 1-3]

### **Tips for Success in DSP**

*Active and consistent participation* is the single-most important contributor to effective learning in this course. This way, you place yourself in the best position to succeed. Teaching and learning are *social activities*, so take advantage of office hours, group work, and your team project to support your learning and gain a more thorough understanding of the ideas underlying this course.

*Be creative and explore!* Past projects often integrated ideas from signal processing and a wide variety of projects, some obvious and conventional, and others more exploratory and highly creative. Both approaches carry the reward of producing a significant design experience. But, you likely will find the process more satisfying and agreeable if you incorporate something that interests you. Take your time considering project ideas and talk to your friends, classmates, as well as the course staff, as you seek inspiration.

### **Course Policies and Grading**

*Cheating:* This course is governed by the UVA honor code policy. If you are unfamiliar with this policy or have questions, please contact me. In particular, you are expected to do your own work and not to provide assistance to others on individual activities. Plagiarism or copying code or solutions, even with attribution, is considered cheating. Course materials should not be shared or distributed outside this class.

*Attendance:* Students must attend all in-class activities and complete the required preparation/reading. These activities are a major component of the course, so unexcused absences may have a detrimental effect on your grade. Please notify Prof. Weller in advance to arrange to make up the work.

*Late Policy:* Late assignments are not graded unless arrangements prior to the deadline are made with Prof. Weller. Missing a class does not excuse you from submitting assignments due that day. **There will be no exceptions to this policy.**

*Assessment Forms (ECE 6750 only):* If you will submit a skill assessment form for this course, you must give a hard copy of the desired skill assessment to Prof. Weller before the last lecture. **No skill assessments will be completed after the semester concludes.** These are graduation requirements for some graduate degrees, so consider in advance which course to use for each skill assessment.

*Disabilities:* Students who need to make arrangements for disabilities should work with the Student Disability Access Center or other appropriate office and provide me with documentation detailing the accommodations requested. All reasonable efforts will be made to ensure these needs are met.

*Grading:* Grades will be assigned according to this scale: 93=A / 90=A- / 87=B+ / 83=B / 80=B- / 77=C+ / 73=C / 70=C- / 67=D+ / 63=D / 60=D- / below=F. I may adjust these thresholds downward to reflect the actual difficulty of the class, but I will not set these thresholds above what are listed here.

Course Calendar and Important Dates (Tentative)

Date	Questions to Explore
Jan. 18-30	<b>What are digital signals and systems, and how do we describe them?</b>  Read Chapters 1, 2 (properties & DTFT), and 3 of DSP 3/E. Implement digital systems in MATLAB during in-class group activities and in individual homework programming questions. Consider why the basic properties of systems (e.g., linearity) are important in the context of using or analyzing those systems.
Feb. 1-6	<b>How do we use DSP in real world applications?</b>  Read Chapter 1 of Tan and Jiang, Digital Signal Processing, 2 <sup>nd</sup> ed. [available online] on signal processing systems. Discuss as a group how to divide and integrate large-scale DSP problems (now in a principled way) and team project approach.
Feb. 8-20	<b>How do digital systems interact with the real world, and what implications does sampling/reconstruction have for the design of these systems?</b>  Read Chapters 2 (random signals), 4 in DSP 3/E. Explore sampling and quantization process using MATLAB. Reflect on considerations for nonideal sampling, quantization errors and connections to prefiltering and noise shaping.  <u>Project Proposal due 2/13.</u>
Feb. 22-Mar. 13	<b>What types of digital systems and filters are used, how do we identify them, and how do we describe their behavior?</b>  Read Chapter 5 in DSP 3/E. Examine filter types and plot frequency responses, pole-zero diagrams using MATLAB in class and in homework. Reflect on how the type of filter (e.g., minimum phase) may influence its implementation or its functionality in a real system.  <u>Midterm Exam 1 on 2/27.</u>  <u>[SEAS Drop without penalty: 3/1] Spring Break (no classes) 3/6 and 3/8.</u>
Mar. 15-27	<b>What different ways are there to design and implement digital filters?</b>  Read Chapters 6, 7 in DSP 3/E. Practice designing IIR and FIR filters that meet certain specifications, and derive specifications from design requirements and desired figures of merit [rich activity]. Understand filter designs methods and advantages/disadvantages of each in the

context of precision, aliasing, coefficient quantization, and filter length.

Milestone 1 due 3/15. [SEAS Drop with "W": 3/15]

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**Mar. 29-Apr. 12    How can the Discrete Fourier Transform be used to represent and implement digital systems like filters?**

Read Chapters 8, 9 in DSP 3/E.

Compare linear and circular convolution and DTFT and DFT using MATLAB. Connect concepts like filtering, resampling, and modulation with DFT operations. Strategically problem solve larger-scale DSP system designs, implementations [rich activity].

Milestone 2 due 3/29.

Midterm Exam 2 on 4/10.

Milestone 3 due 4/12.

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**Apr. 17-24        How can we analyze digital signals using these tools?**

Read Chapter 10 in DSP 3/E.

Explore spectra of stationary and nonstationary real world signals, evaluating features like frequency range, noise level, signal power. Understand limitations of periodogram/spectrogram-based spectral analysis.

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**Apr. 26-May 1    How do we integrate DSP components in real world systems?**

Read [TBD] on DSP system integration.

Discuss as a group how to integrate components of large-scale systems. Identify opportunities for further learning related to DSP (e.g., courses).

Final written reports and presentations are due on 5/1.

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**Final (May 11)    How do teams solve complex real world problems using concepts in DSP?**

Do final presentations for team projects during final exam time slot.